OUTLINE OF THE PROPOSED TOPIC OF RESEARCH

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Proposed Topic of Research

Evaluation of Relationship between Hydro-Chemical Parameters and Water Quality using Multi-Objective Optimization Techniques

Objective of the Proposed Research

The proposed study is intended to the following objectives:

1. To develop a model to evaluate water quality parameters through hydro-chemical parameters in ground water.
2. To find out the proportion of contribution of a chemical parameter to the quality of water in a specific region.
3. To develop a model to evaluate water quality parameters through chemical parameters in industrial effluent.
4. To analyze the relationship between chemical parameters and water quality using the models developed through above objectives.
5. To study the effect of rain on ground water quality using the model developed through objective 1.

Background of the Proposed Research

Introduction

Ground water has become one of the important sources of water for meeting the requirements of various sectors in the country in the last few decades. It plays a vital role in India's economic development and in ensuring its food security. Groundwater is one of the major sources of supply for domestic, industrial and agricultural purposes. In some areas groundwater is the only dependable source of supply, while in some other regions it is chosen because of its ready availability. The rapid pace of agricultural development, industrialization and urbanization has resulted in the overexploitation and contamination of ground water resources in parts of the country, resulting in various adverse environmental impacts and threatening its long-term sustainability.

A WaterAid report on water resources in rural India states that:

a) India has 16 per cent of the world's population and four per cent of its fresh water resources.
b) Estimates indicate that surface and ground water availability is around 1,869 billion cubic meters (BCM). Of this, 40 per cent is not available for use due to geological and topographical reasons.
c) Around 4,000 BCM of fresh water is available due to precipitation in the form of rain and snow, most of which returns to the seas via rivers.
d) Ninety two per cent groundwater extracted is used in the agricultural sector, five and three per cent respectively for industrial and domestic sector.
e) Eight nine per cent of surface water use is for agricultural sector and two per cent and nine per cent respectively are used by the industrial and domestic sector[1]

The composition of water varies widely with local geological conditions. Neither groundwater nor surface water has ever been chemically pure H_2O, since water contains small amounts of gases, minerals and organic matter of natural origin. The total concentrations of substances dissolved in fresh water considered to be of good quality can be hundreds of mg/l.

The ground water available in the country, in general, is potable and suitable for various usages. However, localized occurrence of ground water having various chemical constituents in excess of the limits prescribed for drinking water use has been observed in almost all the states. The commonly observed contaminants such as Arsenic, Fluoride and Iron are geogenic, whereas contaminants such as nitrates, phosphates, heavy metals etc. owe their origin to various human activities including domestic sewerage, agricultural practices and industrial effluents.

Ground water contains a wide variety of dissolved inorganic chemical constituents in various concentrations, resulting from chemical and biochemical interactions between water and the geological materials. Inorganic contaminants including salinity, chloride, fluoride, nitrate, iron and arsenic are important in determining the suitability of ground water for drinking purposes.

Surface water is found extremely variable in its chemical composition due to variations in relative contributions of ground water and surface water sources. Other factors like discharge of city wastewater, industrial waste and mixing of waters can also affect the nature and concentration of minerals in surface water. The chemical composition of ground water will vary depending upon several factors like frequency of rain, which will leach out the salts, time of stay of rain water in the root-zone and intermediate zone, presence of organic matter etc. It may also be pointed out that the water front does not move in a uniform manner as the soil strata are generally quite heterogeneous. The overall effect of all these factors is that the composition of ground water varies from time to time and from place to place.

Ground Water Quality Monitoring

The International Standard Organization (ISO) has defined monitoring as, "The programmed process of samplings, measurements and subsequent recording or signaling or both, of various water characteristics, often with the aim of assessing, conformity to specified objectives". A systematic plan for conducting water quality monitoring is called Monitoring Program, which includes monitoring network design, preliminary survey, resource estimation, sampling, analysis, data management & reporting.

Monitoring of ground water quality is an effort to obtain information on chemical quality through representative sampling in different hydrogeological units. Ground Water is commonly

tapped from phreatic aquifers through dug wells in a major part of the country and through springs and hand pumps in hilly areas. The main objective of ground water quality monitoring program is to get information on the distribution of water quality on a regional scale as well as create a background data bank of different chemical constituents in ground water.[2]

Multiobjective Optimization Techniques

In the world around us it is rare for any problem to concern only a single value or objective. Multiple, often conflicting objectives arise naturally in most real-world optimization scenarios. In our daily lives or in professional settings, there are typically multiple conflicting criteria that need to be evaluated in making decisions. In purchasing a car, cost, comfort, safety, and fuel economy may be some of the main criteria we consider. In portfolio management, we are interested in getting high returns but at the same time reducing our risks. In service industry, customer satisfaction and the cost of providing service are two conflicting criteria that would be useful to consider. Maximizing profit and minimizing the cost of a product; maximizing performance and minimizing fuel consumption of a vehicle; and minimizing weight while maximizing the strength of a particular component are examples of multi-objective optimization problems.

Some of the most popular MCDM methods are Goal Programming, Analytical Hierarchy Process (AHP), Analytical Network Process (ANP), Superiority and Inferiority Method (SIR), Weighted Sum Method (WSM), Weighted Product Method (WPM) etc.

Literature Review of Research Topic

In view of the increasing concerns about the deterioration in ground water quality and as a follow up of one of the important recommendations of the 2nd meeting of the Advisory Council on Artificial Recharge to Ground Water during September 2007, a report entitled 'Ground Water Quality in Shallow Aquifers of India' has been prepared by Central Ground Water Board. The report attempts to summarize various aspects of ground water quality in the shallow aquifers in the country with special reference to six parameters viz. salinity, chloride, arsenic, fluoride, iron and nitrate. [2]

Rational people attempt to make the "best" decision within a specified set of possible alternatives. An optimal, average level of tax collected maximizes the revenue available for the common good, while maintaining a sufficient incentive for individuals to earn income from their own work. One of the first individuals to consider such tradeoffs was F.Y Edgeworth. In 1881 at King's College (London) and later at Oxford, economics Professor F.Y. Edgeworth was the first to define an optimum for multicriteria economic decision making (Edgeworth 1881). In 1893, Pareto created his two most famous theories: Circulation of the Elites and the Pareto Optimum. The second has found broad acceptance (Pareto 1906): "The optimum allocation of the resources of a society is not attained so long as it is possible to make at least one individual better off in his own estimation while keeping others as well off as before in their own estimation."[3]

Multi-objective optimization is the process of simultaneously optimizing two or more conflicting objectives subject to certain constraints. Structuring complex problems well and considering multiple criteria explicitly lead to more informed and better decisions. There have been important advances in this field since the start of the modern multiple criteria decision making discipline in the early 1960s. The translation of Pareto's work into English in 1971 spurred the development of multi-objective methods in Applied Mathematics and Engineering. The growth of this field manifested itself particularly strongly in the United States with pioneering contributions by (Stadler 1979), (Steuer 1985) and many others. [4]

The goal of a formal mathematical optimization-based groundwater management model is to achieve a specified objective in the best possible manner within the various limiting restrictions. The limiting restrictions are derived from managerial considerations and physical behaviour of the system. Water resource management decisions are typically guided by multiple objectives measured in different units. Groundwater management problems are often formulated as multiple objective mathematical programming problems with many conflicting and non-commensurable objectives. [5]

Willis (1977) used response equations as embedded constraints in a multiple objective optimization model for groundwater quality management. The multiple objectives were: (a) maximize the minimum hydraulic head within the pumping region of the groundwater basin, i.e., minimize operational costs of pumping, (b) minimize the minimum head within the injection

region of the aquifer i.e. minimize injection, and (c) minimize the surface waste water storage capacity i.e. maximize injection rates.[6]

Shamir et al (1984) addressed the annual operation of a coastal aquifer in the light of multiple objectives and constraints dictated by long-range considerations. The multiple objective linear programming model was based on a multicell model of the aquifer and network representation of the hydraulic distribution system. The constraint method (Cohon & Marks 1975) of multiple objective analyses was used to obtain trade-off functions between pairs of objectives.[7] Willis & Liu (1984) presented the application of an optimization model to the Yun Lin groundwater basin in southwestern Taiwan. Parametric linear programming was used to generate optimal planning policies and the set of non-inferior solutions. The objectives were to determine the trade-offs associated with additional groundwater development and agricultural demands. [8]

Datta & Peralta (1986) applied surrogate worth trade-off method of multiple objective programming to conjunctive groundwater and surface water management. They presented a set of interactive, computer graphics-based procedures in relation to surrogate worth trade-off method to select a single strategy from a non-dominated set of solutions. [9] Peralta & Datta (1990) approached the multiple objective problem by simultaneously changing entire sets of bounds or boundary conditions. This approach is practical when a model uses a large number of bounds or constraints to represent spatially distributed implicit objectives. They used the embedding technique with linear and quadratic programming. The objectives were (i) maximization of the total withdrawal from the aquifer subject to sustained yield hydraulic constraints, and (ii) maximization of the sustainable maintenance of a specified spring time potentiometric surface. [10]

Yazicigil (1990) presented multiple objective groundwater management models to determine the optimal planning and operation of a multiaquifer system. He used response matrix approach with linear and quadratic programming techniques.[11] Bogardi et al (1991) presented an interactive multiobjective decision-making method for analyzing groundwater management problems. The objectives were: maximization of total yield, minimization of maximum compression at 10 preselected wells, and minimization of total pumping cost.[12] Shafike et al (1992) used three different multicriteria decision-making techniques, viz., compromise programming, Electre III,

and MCQA II, to analyze and rank discrete sets of alternatives in groundwater contamination management problem.[13] Duckstein et al (1994) applied four multicriteria decision making techniques for ranking groundwater management alternatives. These techniques were compromise programming, Electre III, multiattribute utility function, and UTA. The objectives were to optimize pumping yield, total costs, and water-shortage risks.[14] El Magnouni & Treichel (1994) presented a multiple objective linear programming based approach to groundwater quantity (hydraulic) management.[15] Simonovic et al. (1997) showed a Spatial comparison of floodplain management alternatives in a raster GIS environment is conceptualized as a multi criteria decision making problem. A spatial MCDM technique is developed by combining the conventional Compromise Programming technique with GIS technology. This new technique is referred to herein as Spatial Compromise Programming (SCP). The main contribution of the proposed technique is its ability to address uneven spatial distribution of criteria values in the evaluation and ranking of alternatives. SCP is used to determine the best alternative for each geographic location within the region of interest [16].

Gerald Eder et al. (1998) applied MCDM concept is not only to provide possible solutions for a hydro ecological problem but also to shed light on the discriminating capabilities of criteria. The aim is to identify a subset of a given set of criteria used to seek a satisfactory solution among several possible water resource projects being designed for the Austrian part of the Danube between Vienna and the Slovakian border.[17] Das (2001) focused on optimization techniques in ground water quality and quality management. To solve optimization based ground water management models, various mathematical programming techniques such as Linear programming (LP), Non –Linear Programming (NLP), Mixed Integer Programming (MIP) , Optimal theory based mathematical programming, Differential Dynamic Programming (DDP), Stochastic Programming (SP), Combinatorial Optimization (CO) and multiple objective programming for multipurpose management are used.[18]

Shirangi et al. (2008) developed an algorithm combining a multi-objective genetic algorithm (GA) – based optimization model and a water quality simulation model and a water quality simulation model for determining a trade-off curve between objectives related to the allocated water quantity and quality.[19] Niksokhan et al. (2009a) designed a game theory-based methodology for estimating equitable and efficient treatment cost allocation among dischargers

in a river system considering their conflicting interests. They also considered different coalitions among dischargers.[20] Niksokhan et al. (2009b) presented an efficient methodology for developing pollutant discharge permit trading in river systems considering the conflict of interests involving decision makers and stakeholders. In their methodology, a trade-off curve between objectives was developed using the non-dominated sorting GA II. The objective functions were related to the total treatment cost and a fuzzy risk of violating the water quality standards. Finally, an optimization model provided the trading discharge permit policies.[21] Bazargan-Lari et al. (2009) and Kerachian et al. (2009) proposed two conflict resolution models for conjunctive use of surface and groundwater resources considering the water quality issues. They applied their models to the Tehran Aquifer in the Tehran metropolitan area. [22] Alias, et.al. (2009) presented the application of Fuzzy Analytic Hierarchy Process (FAHP) to rank alternatives to find the most reasonable and efficient use of river system. The overall aspects of river system including both qualitative and quantitative are emphasized. [23]

Wu et al. (2010) and Li et al. (2010a) carried out water quality assessments in Jingyuan and Pengyang County, China, respectively. Their studies showed that the water quality in the two counties was in general good except for some areas. The water quality in the two regions was influenced by hydro geological conditions and anthropogenic activities. [24][25] Peiyue et. al. (2010) used osculating value method to perform groundwater quality assessment in No. 2 water source site of Dawukou District, Northwest China and information entropy was used to determine the weight of each assessment parameter.[26] Mahjouri, et.al. (2010) developed two cooperative and non-cooperative methodologies for a large-scale water allocation problem in Southern Iran. [27] Yilmaz, et.al. (2010) developed a water resource management model that facilitates indicator based decision with respect to the environmental, social and economic dimensions in a multiple criteria perspective for the Gediz River Basin in Turkey. The study has delineated the best management alternatives on the basis of 3 different multi criteria decision making methods, including Simple Additive Weighting , Compromise Programming and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).[28]

Sharma et al. (2010) developed models relating to water chemical quality parameters to a set of independent chemical variables. This paper mainly focuses on predicting chemical quality parameters to a set of independent chemical variables in post and pre-monsoon seasons in the

Toda raising area of Tonk district, Rajasthan (India) by using goal programming model to solve the multiple regression equation with an aid of MSExcel and TORA computer software packages.[29] Yang et.al. (2011) quantified the transformed effectiveness of alternatives for watershed management caused by climate change and urbanization and prioritizes five options using multi-criteria decision making techniques.[30] Baba and Tayfur (2011) identified the groundwater pollution in Turkey and the effects of polluted groundwater on human health. [31] Choi and Lee (2011) discussed the natural attenuation capacity of a petroleum contaminated groundwater at a military facility in Korea. [32] Hamzaoui-Azaza et al. (2011) conducted a hydrochemical and statistical investigation, discussed the sources of dissolved ions and assessed the chemical quality of the groundwater in Zeuss–Koutine aquifer, southeastern Tunisia. [33] Peiyue et al. (2012) presented a quality assessment of phreatic water. For the study purpose 20 samples and 10 indices were collected from the study area for the comprehensive water quality assessment and TOPSIS methods and osculating value method were applied. [34]

Gaps in Existing Research

- Multi-objective optimization techniques have been used by number of researchers mainly in water resource management, water allocation, groundwater quality assessment etc. but not on modeling of the chemical parameters and water quality relationship.
- There is very less work available that studies the effect of a hydro-chemical parameter on water quality and analyzes the model using these techniques.
- Several multi-objective optimization techniques have been used for assessing water quality, one technique that gives best water quality model is yet to be identified.
- There is a lot of scope for study on waste water management especially industry effluent management, using multi-objective optimization techniques so that water pollution can be controlled.

Multi-objective optimization techniques may be a handy tool for small scale industries, farmers and for the agencies managing drinking water management which can provide them a model to evaluate water quality through hydro-chemical parameters. The limitation of this study is that there is a lot of variation in chemical parameters exist in ground water of different regions, therefore to develop an integrated model of multiple regions is seen to be a challenge.

Research Design and Methodology

A mathematical model is proposed to evaluate water quality through chemical parameters in the water available in a region. The study is proposed to be on different water types like, inland surface water for irrigation, industrial effluent and drinking water. The study may suggest the mathematical models to those small scale industries that hesitate in going to the laboratories to know the quality of industry effluent they are discharging in the water so that they can control the chemical parameter in discharged effluent.

Based on the objectives set for the present study and the background work reported in literature with their limitations, the methodology of the present study is proposed as follows:

- **Phase 1: Literature Survey**

An in-depth review of literature is proposed to study the techniques that have been used so far in water quality management. Continuous literature survey will be carried out to collect the information required during various stages of the proposed research. The source of this literature survey will be various available journals like, Chemical Engineering Science, School of Environmental Science and Engineering, Journal of Environmental Sciences, International Journal of Water Resources etc., internet sites and e-journals source like Science Direct subscribed through library.

- **Phase 2: Identifying the regions to be studied**

In the second phase of the research the identification of the regions where the water samples have to be collected from, will take place. Sample size will be decided based on condition of a region and the water samples will be collected from different regions under different conditions. Variability of existing chemical parameters in the water and variability of water quality in a region will be deciding criteria to select that region. For example, one group of water samples may be from the region where fluoride (F) is within the tolerance limit i.e., 1.5 and another sample may be from the region where F is beyond the tolerance limit.

- **Phase 3: Collection of water samples**

Water samples will be collected from the identified regions in phase third. Collecting water samples is a continuous process for one year as it depends on 'monsoon' season. The different conditions for collecting water samples may be pre-rain, during rain or post rain seasons.

- **Phase 4: Testing water samples**

In phase 4, the collected samples will be sent to laboratories to determine various chemical parameters and water quality parameters.

- **Phase 5: Analysis of the samples**

In phase five, the analysis of the samples will be conducted. A mathematical model will be developed based on the chemical parameters and water quality parameters found in the collected water samples. The purpose of this model will be to show proportion of contribution of a chemical parameter to the quality of water in a specific region.

Phase 6: Conclusion and Thesis writing

In this phase, all the experimental and theoretical work carried out in different phases will be documented in the form of thesis.

The following techniques are proposed to be used to develop and analyze the model:

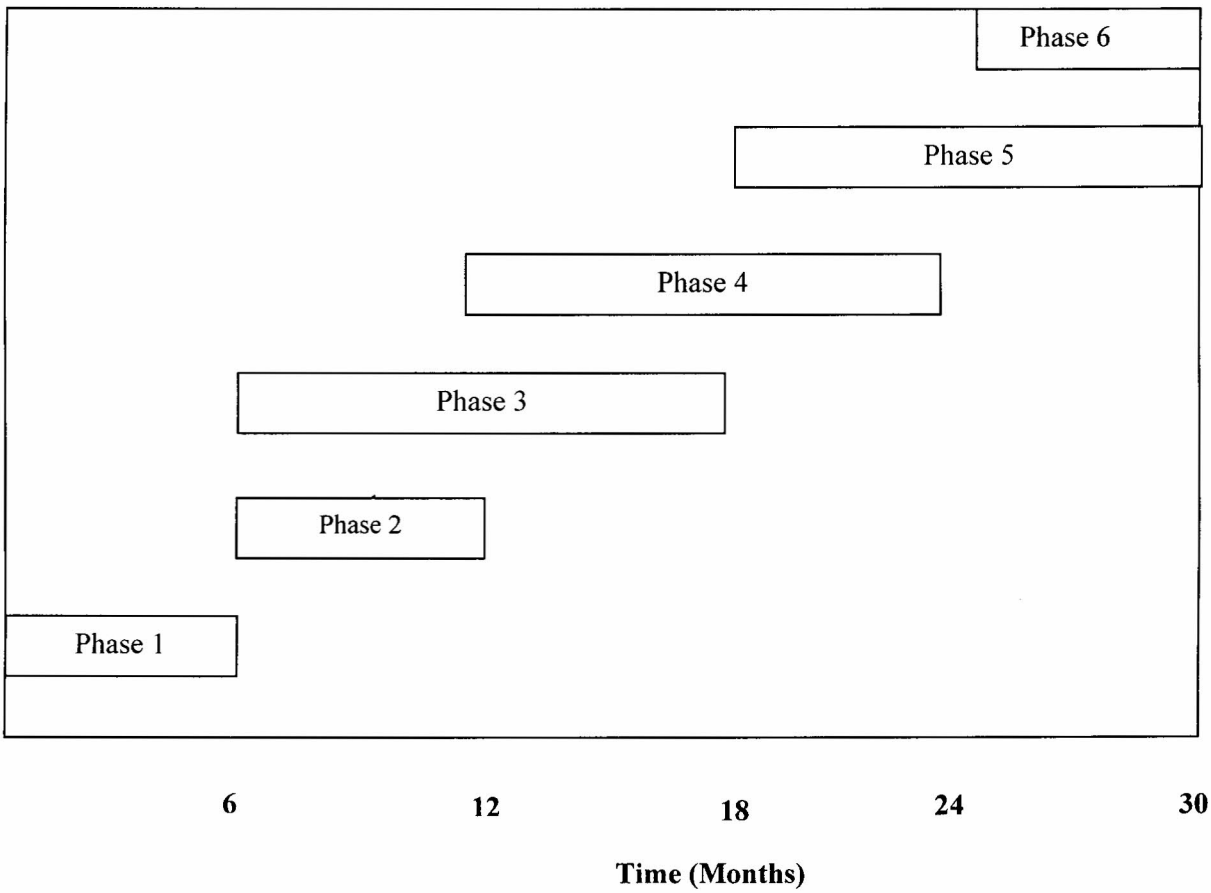
1. Regression Analysis (Linear or Non-linear regression with or without interaction effect)
2. Multi-objective optimization techniques

Different multi-objective optimization techniques are proposed to be used to know the extent of dependency of water quality on chemical parameters. These factors are proposed to be calculated using different software tools, like, AMPL, TORA, LINDO, LINGO, etc. TORA is an algorithm or a set of mathematical instructions in the area of operation research that can be executed in automated and tutorial mode (Hamdy A. Taha [2008]). The software is a tutorial package for novice, as is menu driven and widows-base, which makes it user friendly in solving simplex problems. Alternative methods other than regression analysis may also be used based on necessity, if any arises further during the investigations.

Work Plan

The work-plan for the above-mentioned six activities is shown in figure 1.

Figure 1: WORK PLAN



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